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The Cause and the Remedy

BY

GEORGE L. VOSE

AUTHOR OF "MANUAL FOR RAILROAD ENGINEERS AND ENGINEERING STUDENTS," "LIFE AND WORKS OF GEORGE W. WHISTLER, CIVIL ENGINEER," ETC.

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NOTE.

THE substance of the following pages appeared originally in "The Railroad Gazette." It was afterwards reproduced in pamphlet form, and has since been several times delivered as an address to various bodies, the last occasion being before the Legislature of Massachusetts, 1887. It is now re-published, with some new matter added, in the hope that the public attention may be called to a subject which has so important a bearing upon the public safety.

BRIDGE DISASTERS IN AMERICA.

NEARLY all of the disasters which occur from the breaking down of bridges are caused by defects which would be easily detected by an efficient system of inspection. Not less than forty bridges fall in the United States every year. No system of public inspection or control at present existing has been able to detect in advance the defects in these structures, or to prevent the disasters. After a defective bridge falls, it is in nearly every case easy to see why it did so. It would be just about as

easy, in most cases, to tell in advance that such a structure would fall if it ever happened to be heavily loaded. Hundreds of bridges are to-day standing in this country simply because they never happen to have received the load which is at any time liable to come upon them.

A few years ago an iron highway bridge at Dixon, Ill., fell, while a crowd was upon it, and killed sixty persons. The briefest inspection of that bridge by any competent engineer would have been sure to condemn it. A few years later the Ashtabula bridge upon the Lake Shore Railroad broke down under an express train, and killed over eighty passengers. The report of the committee of the Ohio Legislature appointed to investigate that disaster concluded, first, that the bridge went down under an ordinary load by

reason of defects in its original construction; and, secondly, that the defects in the original construction of the bridge could have been discovered at any time after its erection by careful examination. Hardly had the public recovered from the shock of this terrible disaster when the Tariffville calamity added its list of dead and wounded to the long roll already charged to the ignorance and recklessness which characterize so much of the management of the public works in this country.

There are many bridges now in use upon our railroads in no way better than those at Ashtabula and Tariffville, and which await only the right combination of circumstances to tumble down. There are, by the laws of chance, just so many persons who are going to be killed on those bridges. There are

hundreds of highway bridges now in daily use which are in no way safer than the bridge at Dixon was, and which would certainly be condemned by five minutes of competent and honest inspection. More than that, many of them have already been condemned as unfit for public use, but yet are allowed to remain, and invite the disaster which is sure to come. Can nothing be done to prevent this reckless and wicked waste of human life? Can we not have some system of public control of public works which shall secure the public safety? The answer to this question will be, Not until the public is a good deal more enlightened upon these matters than it is now.

It has been very correctly remarked, that, in order to bring a disaster to the public notice, it must be emphasized by loss of life.

The Ashtabula bridge fell, and killed over eighty persons; and a storm of indignation swept over the country, from one end to the other. No language was severe enough to apply to the managers of the Lake Shore Railroad; but if that very bridge had fallen under a freight-train, and no one had been injured, the occurrence would have been dismissed with a paragraph, if, indeed, it had received even that recognition. In February, 1879, a span one hundred and ten feet long of an iron bridge on the Chicago and Alton Railroad at Wilmington fell as a train of empty coal-cars was passing over it, and three cars were precipitated into the river, a distance of over thirty feet. No one was injured. Not a word of comment was ever made in regard to this occurrence. Suppose, that, in place of empty coal-cars, the train had con-

sisted of loaded passenger-cars, and that one hundred persons had been killed. We know very well what the result would have been. Is not the company just as much to blame in one case as the other? On the night of the 8th of November, 1879, one span of the large bridge over the Missouri at St. Charles gave way as a freight-train was crossing it, and seventeen loaded stock-cars fell a distance of eighty feet into the river. Two brakemen and two drovers were killed. This bridge, says the only account that appeared in the papers, did not break apparently, for the whole span "went down" with the cars upon it. It could hardly make much difference to the four men who were killed, whether the bridge broke down, or "went" down. Not a word of comment was ever made in the papers outside of Missouri in regard to this disaster.

Suppose, that, in place of seventeen stock-cars, half a dozen passenger-cars had fallen from a height of eighty feet into the river, and that, in place of killing two brakemen and two drovers, two or three hundred passengers had been killed. Is not the public just as much concerned in one case as in the other?

Suppose that a bridge now standing is exactly as unsafe as the Ashtabula bridge was the day before it fell, would it be possible to awaken public attention enough to have it examined? Probably not. About two years ago an attempt was made to induce one of the leading dailies in this country to expose a wretchedly unsafe bridge in New England. The editor declined, on the ground that the matter was not of sufficient interest for his readers; but less than a month afterwards he devoted three columns

of his paper to a detailed account of a bridge disaster in Scotland, and asked why it was that such things must happen, and if there was no way of determining in advance whether a bridge was safe, or not?

This editor certainly would not maintain, that, in itself, it was more important to describe a disaster after it had occurred than to endeavor to prevent the occurrence; but, as a business man, he knew perfectly well that his patrons would read an account giving all of the sickening detail of a terrible catastrophe, while few, if any, would wade through a dry discussion of the means for protecting the public from just such disasters. The public is always very indignant with the effect, but does not care to trouble itself with the cause; but the effect never will be prevented until the cause is

controlled; and the sooner the public understands that the cause is in its own hands, to be controlled, or not, as it chooses, the sooner we shall have a remedy for the fearful disasters which are altogether too common in the United States.

In a country where government controls all matters on which the public safety depends, and where no bridge over which the public is to pass is allowed to be built except after the plans have been approved by competent authority, where no work can be executed except under the rigid inspection of the best experts, nor opened to the public until it has been officially tested and accepted, it makes little or no difference whether the public is informed, or not, upon these matters; but in a country like the United States, where any man may at any

time open a shop for the manufacture of bridges, whether he knows any thing about the business, or not, and is at liberty to use cheap and insufficient material, and where public officers are always to be found ready to buy such bridges, simply because the first cost is low, and to place them in the public ways, it makes a good deal of difference. There is at present in this country absolutely no law, no control, no inspection, which can prevent the building and the use of unsafe bridges; and there never will be until the people who make the laws see the need of such control.

There is no one thing more important in this matter than that we should be able to fix precisely the blame in case of disaster upon some person to whom the proper punishment may be applied. If every railway

director, or town or county officer, knew that he was held personally accountable for the failure of any bridge in his charge, we should soon have a decided improvement in these structures. If we could show that a certain bridge in a large town had been for a long time old, rotten, worn out, and liable at any moment to tumble down, and could show in addition, that the public officers having charge of such a bridge knew this to be the case, and still allowed the public to pass over it, we can see at once, that, in case of disaster, the blame would be clearly located, and the action for damages would be short and decisive. Once let a town have heavy damages to pay, and let it know at the same time that the town officers are clearly accountable for the loss, and it is possible that it would be willing to adopt some system

that should prevent the recurrence of such an outlay.

To see what may be accomplished by an efficient system of public inspection, it is necessary to know something in regard to the structures to be inspected. We have now in common use in this country, both upon our roads and our railroads, bridges made entirely of iron, bridges of wood and iron combined, and occasionally, though not often nowadays, a bridge entirely of wood; and these structures are to be seen of a great variety of patterns, of all sizes, and in every stage of preservation. Of late so great has been the demand for bridge-work, that this branch of engineering has become a trade by itself; and we find immense works fitted up with an endless variety of the most admirably adapted machine-tools

devoted exclusively to the making of bridges of wood, iron, steel, or all combined. As in all division of labor, the result of this specialization has been to improve the quality of the product, to lessen the cost, and to increase the demand, until many of our large firms reckon the length of bridging which they have erected by miles instead of feet. As usual, however, in such cases, unprincipled adventurers are not wanting, who, taking advantage of a great demand, do not hesitate to fit up cheap shops, to buy poor material, and to flood the market with a class of bridges made with a single object in view, viz., to sell, relying upon the ignorance — or something worse — of public officials for custom. Not a year passes in which some of these wretched traps do not tumble down, and cause a greater or less loss of life, and

at the same time,. with uninformed people, throw discredit on the whole modern system of bridge-building. This evil affects particularly highway bridges. The ordinary county commissioner or selectman considers himself amply competent to contract for a bridge of wood or iron, though he may never have given a single day of thought to the matter before his appointment to office. The result is, that we see all over the country a great number of highway bridges which have been sold by dishonest builders to ignorant officials, and which are on the eve of falling, and await only an extra large crowd of people, a company of soldiers, a procession, or something of the sort, to break down.

Not many years ago, a new highway bridge of iron was to be made over one

of the principal rivers in New England. The county commissioners desired a well-known engineer, especially noted as a bridge-builder, to superintend the work, in order to see that it was properly executed. The engineer, after inspection of the plans, told the commissioners plainly that the design was defective, and would not make a safe bridge; and that, unless it was materially changed, he would have nothing to do with it. The bridge, however, was a cheap one, and, as such, commended itself to the commissioners, who proceeded to have it erected according to the original plan; and these same commissioners now point to that bridge, which has not yet fallen, but which is liable to do so at any time, as a complete vindication of their judgment, so called, as opposed to

that of the engineer who had spent his life in building bridges.

An impression exists in the minds of many persons, that it is purely a matter of opinion whether a bridge is safe, or not. In very many cases, however, — perhaps in most, — it is not at all a matter of opinion, but a matter of fact and of arithmetic. The whole question always comes to this: Is the material in this bridge of good quality? Is there enough of it? Is it correctly disposed, and properly put together? With given dimensions, and knowing the load to be carried, it is a matter of the very simplest computation to fix the size of each member. We know what one square inch of iron will hold, and we know, also, the total number of pounds to be sustained; and it is no matter of opinion, but one of simple

division, how many times one will go into the other.

But it may be asked, Can the precise load which is coming upon any structure be exactly fixed? are not the circumstances under which bridges are loaded very different? Bridges in different localities are certainly subjected to very different loads, and under very different conditions; but the proper loads to be provided for have been fixed by the best authority for all cases within narrow enough limits for all practical purposes. Few persons are aware of the weight of a closely packed crowd of people. Mr. Stoney of Dublin, one of the best authorities, packed 30 persons upon an area of a little less than 30 square feet; and at another time he placed 58 persons upon an area of 57 square feet, the resulting load in the two cases

being very nearly 150 pounds to the square foot. "Such cramming," says Mr. Stoney, "could scarcely occur in practice, except in portions of a strongly excited crowd; but I have no doubt that it does occasionally so occur." "In my own practice," he continues, "I adopt 100 pounds per square foot as the standard working-load distributed uniformly over the whole surface of a public bridge, and 140 pounds per square foot for certain portions of the structure, such, for example, as the foot-paths of a bridge crossing a navigable river in a city, which are liable to be severely tried by an excited crowd during a boat-race, or some similar occasion." Tredgold and Rankine estimate the weight of a dense crowd at 120 pounds per square foot. Mr. Brunel used 100 pounds in his calculations for the Hunger-

ford Suspension Bridge. Mr. Drewry, an old but excellent authority, observes that any body of men marching in step at from 3 to 3½ miles an hour will strain a bridge at least as much as double the same weight at rest; and he adds, "In prudence, not more than one-sixth the number of infantry that would fill a bridge should be permitted to march over it in step." Mr. Roebling says, in speaking of the Niagara Falls Suspension Bridge, "In my opinion, a heavy train, running at a speed of 20 miles an hour, does less injury to the structure than is caused by 20 heavy cattle under full trot. Public processions marching to the sound of music, or bodies of soldiers keeping regular step, will produce a still more injurious effect."

Evidently a difference should be made in determining the load for London Bridge

and the load for a highway bridge upon a New-England country road in a thinly settled district. A bridge that is strong enough is just as good and just as safe as one that is ten times stronger, and even better; for in a large bridge, if we make it too strong, we make it at the same time too heavy. The weight of the structure itself has to be sustained, and this part of the load is a perpetual drag on the material.

In 1875 the American Society of Civil Engineers, in view of the repeated bridge disasters in this country, appointed a committee to report upon The Means of Averting Bridge Accidents. We might expect, when a society composed of some hundreds of our best engineers selects an expert committee of half a dozen men, that the best authority would be pretty well represented;

and such was eminently the case. It would be impossible to have combined a greater amount of acknowledged talent, both theoretical and practical, with a wider and more valuable experience than this committee possessed. The first point taken up in the report is the determination of the loads for which both railroad and highway bridges should be proportioned. In regard to highway bridges, a majority of the committee reported that for such structures the standard loads should not be less than as shown in the following table:—

Span.	Pounds per Square Foot.		
	Class A.	Class B.	Class C.
60 feet and less .	100	100	70
60 to 100 feet . .	90	75	60
100 to 200 feet . .	75	60	50
200 to 400 feet . .	60	50	40

Class A includes city and suburban bridges, and those over large rivers, where great concentration of weight is possible. Class B denotes highway bridges in manufacturing districts having well-ballasted roads. Class C refers to ordinary country-road bridges, where travel is less frequent and lighter. A minority of the committee modified the table above by making the loads a little larger. The whole committee agreed in making the load per square foot less as the span is greater, which is, of course, correct. It would seem eminently proper to make a difference between a bridge which carries the continuous and heavy traffic of a large city, and one which is subjected only to the comparatively light and infrequent traffic of a country road. At the same time it should not be forgotten, that, in a large

part of the United States, a bridge may be loaded by ten, fifteen, or even twenty pounds per square foot by snow and ice alone, and that the very bridges which from their location we should be apt to make the lightest, are those which would be most likely to be neglected, and not relieved from a heavy accumulation of snow. In view of the above, and remembering that a moving load produces a much greater strain upon a bridge than one which is at rest, we may be sure, that, as the committee above referred to recommend, the loads should not be less than those given in the table. We can easily see that in special cases they should be more.

There is another point in regard to loading a highway bridge, which is to be considered. It often happens that a very heavy load is

carried over such bridges upon a single truck, thus throwing a heavy and concentrated load upon each point as it passes. Mr. Stoney states that a wagon with a crank-shaft of the British ship "Hercules," weighing about forty-five tons, was refused a passage over Westminster iron bridge, for fear of damage to the structure, and had to be carried over Waterloo bridge, which is of stone; and he says that in many cases large boilers, heavy forgings, or castings reach as high as twelve tons upon a single wheel. The report of the American Society of Civil Engineers, above referred to, advises that the floor system be strong enough to carry the following loads upon four wheels: Class A, 24 tons; Class B, 16 tons; Class C, 8 tons; though it is stated that these do not include the extraordinary loads sometimes taken over highways.

"This provision for local loads," says Mr. Boller, one of the committee, "may seem extreme; but the jar and jolt of heavy, springless loads come directly on all parts of the flooring at successive intervals, and admonish us that any errors should be on the safe side."

To pass now to railroad bridges, we find here a very heavy load coming upon the structure in a sudden, and often very violent, manner. Experiment and observation both indicate that a rapidly moving load produces an effect equal to double the same load at rest. This effect is seen much more upon short bridges, where the moving load is large in proportion to the weight of the bridge, than upon long spans, where the weight of the bridge itself is considerable. The actual load upon a short bridge is also more per

foot than upon a long one, because the locomotive, which is much heavier than an equal length of cars, may cover the whole of a short span, but only a part of a longer one. The largest engines in use upon our railroads weigh from 75,000 to 80,000 pounds on a wheel-base of not over twelve feet in length, or 2,800 pounds per foot for the whole length of the engine, and from 20,000 to 24,000 pounds on a single pair of wheels. The heaviest coal-trains will weigh nearly a ton to the foot, ordinary freight-trains from 1,600 to 1,800 pounds, and passenger-trains from 1,000 to 1,200 pounds per foot. Any bridge is liable to be traversed by two heavy freight-engines followed by a load of three-quarters of a ton to the foot; so that if we proportion a bridge to carry 3,000 pounds per foot for the total engine length, and one ton per foot

for the rest of the bridge, bearing in mind that any one point may be called upon to sustain 24,000 pounds, and regarding the increase of strain upon short spans due to high speeds, we have the following loads for different spans exclusive of the weight of the bridge:—

Span.	Lbs. per Foot.	Span.	Lbs. per Foot.
12	7,000	50	3,000
15	6,000	100	2,800
20	4,800	200	2,600
25	4,000	300	2,500
30	3,600	400	2,450
40	3,200	500	2,400

The above does not vary essentially from the English practice, and is substantially

the same as given by the committee of the American Society of Civil Engineers.

The load which any bridge will be required to carry being determined, and the general plan and dimensions fixed, the several strains upon the different members follow by a simple process of arithmetic, leaving to be determined the actual dimensions of the various parts, a matter which depends upon the power of different kinds of material to resist different strains. This brings us to the exceedingly important subject of the nature and strength of materials.

It has been said that we know what one square inch of iron will hold. Like the question of loads above examined, this is a matter which has been settled, at any rate within very narrow limits, by the experience of many years of both European

and American engineers. A bar of the best wrought-iron an inch square will not break under a tensile strain of less than sixty thousand pounds. Only a small part of this, however, is to be used in practice. A bar or beam may be loaded with a greater weight applied as a permanent or dead-load than would be safe as a rolling or moving weight. A load may be brought upon any material in an easy and gradual manner, so as not to damage it; while the same load could not be suddenly and violently applied without injury. The margin for safety should be greater with a material liable to contain hidden defects, than with one which is not so; and it should be greater with any member of a bridge which is subjected to several different kinds of strain, than for one which has to resist only a

single form of strain. Respect, also, should be had to the frequency with which any part is subjected to strain from a moving load, as this will influence its power of endurance. The rule in structures having so important an office to perform as railroad or highway bridges, should be, in all cases, absolute safety under all conditions.

The British Board of Trade fixes the greatest strain that shall come upon the material in a wrought-iron bridge, from the combined weight of the bridge and load, at 5 tons per square inch of the net section of the metal. The French practice allows $3\frac{8}{10}$ tons per square inch of the gross section of the metal, which, considering the amount taken out by rivet-holes, is substantially the same as the English allowance. The report of the American Society of Civil

Engineers, above referred to, recommends 10,000 pounds per inch as the maximum for wrought-iron in tension in railroad bridges. For highway bridges a unit strain of 15,000 pounds per square inch is often allowed. A very common clause in a specification is that the *factor of safety* shall be four, five, or six, as the case may be, meaning by this that the actual load shall not exceed one-fourth, one-fifth, or one-sixth part of the breaking-load. It is a little unfortunate that this term, factor of safety, has found its way into use just as it has; for it by no means indicates what is intended, or what it is supposed to. The true margin for safety is not the difference between the working-strain and the breaking-strain, but between the working-strain and that strain which will in any way unfit the material for use. Now,

any material is unfitted for use when it is so far distorted by overstraining that it cannot recover, or, technically speaking, when its elastic limit has been exceeded. The elastic limit of the best grades of iron is just about half the breaking-weight, or from 25,000 to 30,000 pounds per inch. A poor iron will often show a very fair breaking-strength, but, at the same time, will have a very low elastic limit, and be entirely unfit for use in a bridge. A piece of iron of very inferior quality will often sustain a greater load before breaking than a piece of the best and toughest material, for the reason that a tough but ductile iron will stretch before giving way, thus reducing the area of section, while a hard but poor iron will keep nearly its full size until it breaks. A tough and ductile iron should bend double,

when cold, without showing any signs of fracture, and should stretch fifteen per cent of its length before breaking; but much of the iron used in bridges, although it may hold 40,000 or 50,000 pounds per inch before failing, will not bend over 90 degrees without cracking, and has an elastic limit as low as 18,000 pounds. It is thus full as important to specify that an iron should have a high elastic limit as that it should have a high breaking-weight. A specification which allowed no material to be strained by more than 10,000 pounds per inch, and no iron to be used with a less elastic limit than 25,000 pounds, would, at the same time, agree with the standard requirement, both in England and in the United States, and would also secure a good quality of iron.

Two documents published some time since

illustrate the preceding remarks. The first is the account of the tests of the iron taken from the Tariffville bridge after its failure, and the second is the specification for bridges on the Cincinnati Southern Railroad. The Tariffville bridge, though nominally a wooden one, like most structures of the kind relied entirely upon iron rods to keep the wood-work together. Although the rods were too small, and seriously defective in manufacture, the bridge ought not to have fallen from that cause. The ultimate strength of the iron was not what it should have been, but yet it was not low enough to explain the disaster; but when we look at the *quality* of the iron, we have the cause of the fall. The rods taken from the bridge show an ultimate tensile strength of 47,560 pounds per inch, but an elastic limit

of only 19,000 pounds; while the strain which was at any time liable to come on them was 22,000 pounds per inch, or 3,000 pounds more than the elastic limit. The fracture of the tested rods, which, it is stated, broke with a single blow of the hammer very much in the manner of cast-iron, showed a very inferior quality of metal. The rods broke in the bridge exactly where we should look for the failure; viz., in the screw at the end. No ordinary inspection would have detected this weakness. No inspection *did* detect it, but a proper specification faithfully carried out would have prevented the disaster.

Look now at an extract from the specification for bridges upon the Cincinnati Southern Railway: —

"All parts of the bridges and trestleworks

must be proportioned to sustain the passage of the following rolling-load at a speed of not less than 30 miles an hour: viz., two locomotives coupled, each weighing 36 tons on the drivers in a space of 12 feet, the total weight of each engine and tender loaded being 66 tons in a space of 50 feet, and followed by loaded cars weighing 20 tons each in a space of 22 feet. An addition of 25 per cent will be made to the strains produced by the rolling-load considered as static in all parts which are liable to be thrown suddenly under strain by the passage of a rapidly moving load. A similar addition of 50 per cent will be made to the strain on suspension links and riveted connections of stringers with floor-beams, and floor-beams with trusses. The iron-work shall be so proportioned that the weight

of the structure, together with the above specified rolling-load, shall in no part cause a tensile strain of more than 10,000 pounds per square inch of sectional area. Iron used under tensile strain shall be tough, ductile, of uniform quality, and capable of sustaining not less than 50,000 pounds per square inch of sectional area without fracture, and 25,000 pounds per square inch without taking a permanent set. The reduction of area at the breaking-point shall average 25 per cent, and the elongation 15 per cent. When cold, the iron must bend, without sign of fracture, from 90 to 180 degrees."

A specification like this, properly carried out, would put an absolute stop to the building of such structures as the Tariffville Bridge, and would prevent a very large part of the catastrophes which so often shock

the community, and shake the public faith in iron bridges. Reference has been made above to the proper loads to be placed upon wrought-iron when under a tensile strain. Similar loads have been determined for other materials, and for other kinds of strain.

The preceding remarks in regard to the loads for which bridges should be designed, and the safe weight to be put upon the material, are given to show how far the safety of a bridge is a matter of fact, and how far a matter of opinion. It will be seen that the limits within which we are at liberty to vary, are quite narrow, so that bridge-building may correctly be called a science; and there is no excuse for the person who guesses, either at the load which a bridge should be designed to bear, or at the

size of the different members of the structure. Still less can we excuse the man who not only guesses, but who, in order to build cheaply, persistently guesses on the wrong side.

It will, of course, be understood, when it is said that bridge-building may be called a science, that it can only be so when in the hands of an engineer whose judgment has been matured by wide experience, and who understands that no mechanical philosophy can be applied to practice which is not subject to the contingencies of workmanship. There are many bridges which will stand the test of figures very well, and which are nevertheless very poor structures. The general plan of a bridge may be good, the computations all right, and yet it may break down under the first train that passes over

it. There are many practical considerations that cannot be, at any rate have not yet been, reduced to figures. It is not enough that the strains upon each member of a bridge should be correctly estimated, and fall within the safe limits: the different members of the bridge must be so connected, and the mechanical details such, as to insure, under all conditions, the assumed action of the several parts. In fine, while we can say that a bridge that does not stand the test of arithmetic is a bad bridge, we cannot always say that a structure which does stand such a test is a good one.

We often hear it argued that a bridge must be safe, since it has been submitted to a heavy load, and did not break down. Such a test means absolutely nothing. It does not even show that the bridge will

bear the same load again, much less does it show that it has the proper margin for safety. It simply shows that it did not break down at that time. Every rotten, worn-out, and defective bridge that ever fell has been submitted to exactly that test. More than this, it has repeatedly happened that a heavy train has passed over a bridge in apparent safety, while a much lighter one passing directly afterwards has gone through. In almost all such cases, the structure has been weak and defective; and finally some heavy load passes over, and cripples the bridge, so that the next load produces a disaster. For the test of a bridge to be in any way satisfactory, we must know just what effect such test has had upon the structure. We do not find this out by simply standing near, and noting

that the bridge did not break down. We must satisfy ourselves beyond all question that no part has been overstrained.

A short time ago the builders of a wretchedly cheap and unsafe highway bridge, in order to quiet a fear which had arisen that the structure was not altogether sound, tested a span 122 feet long with a load of 58,000 pounds; and inasmuch as the bridge did not break down under this load, which was less than a quarter part of what it was warranted to carry safely, the county commissioners considered the result eminently satisfactory, and remarked that the test was made merely to satisfy the public that the bridge was abundantly safe for all practical uses. The public would, no doubt, have been satisfied that the Ashtabula bridge was abundantly safe for

all practical uses had it stood on that bridge in the morning and seen a heavy freight-train go over it, and yet that very bridge broke down directly afterwards under a passenger-train.

Now, according to the common notion, that was a good bridge in the morning, and a very bad bridge, or rather, no bridge at all, in the evening. The question for the public is, When did it cease to be a good bridge, and begin to be a bad one? A test like the one referred to above can do no more than illustrate the ignorance or lack of honesty of those who make it, or those who are satisfied with it. Such a test might come within a dozen pounds of breaking the bridge down, and no one be the wiser. The entire absurdity of such testing has recently been illustrated in the most

decided manner. The very same company that built the bridge above referred to, made also another one on exactly the same plan, and of almost precisely the same size, and tested it when done by placing almost exactly the same load upon it. The bridge did not break down; and the county commissioners, for whom the work was done, were satisfied that it was "abundantly safe for all practical uses," accepted it, paid for it; and in less than ten years it broke down under a single team and a little snow, weighing in all not over one-tenth part of the load the bridge was warranted to carry, and not over one-half the load with which it had been previously tested. If this bridge had been "tested" by five minutes of honest arithmetic, it would have been promptly condemned the very day it was finished.

In view of the preceding, what shall we say of a bridge company that deliberately builds a bridge in the middle of a large town, where it will be subjected to heavy teaming, and, owing to its peculiar location, to heavy crowds, and warrants to the town that it shall safely hold a ton per running-foot, when the very simplest computation shows beyond chance of dispute that such a load will strain the iron to 40,000 pounds per square inch? We are to say, either that such a company is so ignorant that it does not know the difference between a good bridge and a bad one, or else so wicked as to knowingly subject the public to a wretchedly unsafe bridge. The case referred to is not an imaginary one, but existed recently in the main street of a large New-England town. The joints in that bridge, which

could safely hold but 20,000 pounds, were required to hold 60,000 pounds under the load which the builders had warranted the bridge to carry safely. The case was so bad, that, after a lengthy controversy, the town officers had a thorough expert examination of the bridge, which promptly condemned it as in imminent danger of falling, and as having a factor of safety of only $1\frac{15}{100}$, which is practically no factor at all. Notwithstanding all this, and in the face of the report, the president of the bridge company came out with a letter in the papers, in which he pronounced the bridge "perfectly safe." Thus we actually have the president of a bridge company in this country stating openly that a factor of safety of $1\frac{15}{100}$ makes a bridge perfectly safe, or, in other words, that a bridge can safely bear

the load that will break it down, for he very wisely made not the slightest attempt to disprove any of the conclusions of the commission; and this company has built hundreds of highway bridges all over the United States, and is building them to-day wherever it can find town or county officers ignorant enough to buy them.

It might be supposed, that, under the above condemnation, the authorities controlling the bridge would have taken some steps to prevent the coming disaster. They did, however, nothing of the kind, but allowed the public to travel over it for more than a year, at the most fearful risk, until public indignation became so strong that a special town-meeting was called, and a committee appointed to remove the old bridge, and to build a new one.

One of the worst cases of utterly dishonest bridge-building that we have had of late years in Massachusetts, was that of the iron highway bridge across the Merrimac River at Groveland, a few miles below Haverhill, one span of which broke down in January, 1881. This bridge was built in 1871–1872, and consisted of 6 spans, each about 125 feet long. The whole cost of the structure was $80,000, and the contract price for the iron-work was $28,000. The company which made that bridge, agreed in their contract to give the county a structure that should carry safely 3,000 pounds per running-foot besides its own weight; but they built a bridge, which, if they knew enough to compute its strength at all, they knew perfectly well could not safely carry over one-quarter part of that

load. In fact, the weight of the bridge alone is more than it ever ought to have borne. The company warranted each span of that bridge to carry safely a net or moving load of 165 tons, and it broke down under a single team and a small amount of snow. The company warranted that bridge to carry safely a load which would strain the iron to 50,000 pounds per inch, when it knew perfectly well that 15,000 pounds per inch was the most that could safely be borne.

There are several concerns in the United States which make a specialty of highway bridges, and which, taking advantage of the ignorance of public officials, are flooding the country with bridges no better than that at Groveland. On an average, at least twenty of these miserable traps tumble

down every year, and nothing is done to bring the guilty parties to punishment. Dishonest builders cheat ignorant officials, and the public suffers the damage and pays the bills. Is human life worth enough to pay for having these structures inspected, and, if found unsafe, strengthened or removed? Can we do any thing to prevent towns and counties from being imposed upon by dishonest builders? We certainly can, if those who control these matters care enough about it to do it. There are two ways of buying a bridge, — a good way and a bad one; and these two ways are so plain that no one can misunderstand. To buy a bad bridge, just as soon as your town or county votes money for a new bridge, certain agents — and they are as numerous as the agents for sewing-ma-

chines or lightning-rods — will call on, or write to, the town or county officers, and will offer to build any thing under heavens you want of any size, shape, or material, and for almost any price. They will produce testimonials from all the town and county officers in the country for the excellence of their bridges, and would not hesitate to give reference, even, for their moral character, if you should ask it. If they find that you don't know any thing about bridges, they will, to save you the trouble, furnish a printed specification; which document will commit you to pay the money, but will not commit the bridge company to any thing at all. When the bridge is put up, you never will know whether the iron is good or bad, nor whether the dimensions and proportions are such as to be

safe or not. You will know that you have paid your money away, but you never will know what you have got for it until some day when your bridge gets a crowd upon it, and breaks down, and you have the damage to pay. This mode of buying a bridge is very common. To buy a good bridge, first determine precisely what you want; and if you don't know any thing in regard to bridge-building yourself, employ an engineer who does, to make a specification stating exactly what you want, and what you mean to have. Then advertise for bridge-builders to send in plans and proposals. Let the contractors understand that all plans and computations are to be submitted to your engineer, that all materials and workmanship will be submitted to your inspectors, and that the whole struc-

ture is to be made subject to the supervision of a competent engineer, and accepted by him for you. You will find at once, that, under such conditions, all travelling agents and builders of cheap bridges will avoid you as a thief does the light of day. You will have genuine proposals from responsible companies, and their bids should be submitted to your engineer. When you have made your choice, let the contract be written by your lawyer, and have the plans and specifications attached. Employ a competent engineer to inspect the work as it goes on; and when it is done, you will have a bridge which will be warranted absolutely sound by the best authority. This mode of buying a bridge is very uncommon.

The Ashtabula bridge, it is stated in the

report of the committee of the Ohio Legislature appointed to investigate that disaster, had factors, — we can hardly call them factors of safety, — in some parts as low as $1\frac{6}{10}$ and $1\frac{2}{10}$, such factors referring to the breaking-weight; and even these factors were obtained by assuming the load as at rest, and making no allowance for the jar and shock from a railroad train in motion. Well may the commissioners say, as they do at the end of their report, "The bridge was liable to go down at any time during the last ten years under the loads that might at any time be brought upon it in the ordinary course of the company's business, and it is most remarkable that it did not sooner occur."

One point always brought forward when an iron bridge breaks down, is the supposed

deterioration of iron under repeated straining; and we are gravely told that after a while all iron loses its fibre, and becomes crystalline. This is one of the "mysteries" which some persons conjure up at tolerably regular intervals to cover their ignorance. It is perfectly well known by engineers the world over, that with good iron properly used, nothing of the kind ever takes place. This matter used to be a favorite bone of contention among engineers, but it has long since been laid upon the shelf. No engineer at the present day ever thinks of it. We have only to allow the proper margin for safety, as our first-class builders all do, and this antiquated objection at once vanishes. The examples of the long duration of iron in large bridges are numerous and conclusive. The Niagara-Falls railroad suspension bridge was carefully inspected

after twenty-five years of continued use under frequent and heavy trains, and not only was it impossible to detect by the severest tests any defect in the wire of the cables, but a piece of it, being thrown upon the floor, curled up, showing the old "kink" which the iron had when it was first made, and wound on the reel. The Menai suspension bridge, in which 1,000 tons of iron have hung suspended across an opening of 600 feet for sixty years, shows no depreciation that the most rigid inspection could detect. Iron rods, recently taken from an old bridge in this country, have been carefully tested after sixty years of use, and found to have lost nothing, either of the original breaking-strength, or of the original elasticity.

The question is frequently asked, Does

not extreme cold weaken iron bridges? To this, it may be replied, that no iron bridge, made by a reliable company, has ever shown the slightest indication of any thing of the kind, though they have been used for many years in Russia, Norway, Sweden, and Canada, and nothing that we know in regard to iron gives us any reason to suppose that any thing of the kind ever will happen. But here, again, every thing turns upon the quality of the iron. Iron containing phosphorus is "cold-short," or brittle when cold, and will break quicker under repeated and sudden shocks in cold weather than when it is warm. With good iron, properly used, we need have no fear on this point. The securing such iron is a matter to which the utmost attention is paid by our first-class bridge-building firms, but it is a matter to

which no attention is paid by the builders of cheap bridges. We might suppose that a person, in putting an insufficient amount of iron into a bridge, would be careful to get the best quality; but exactly the reverse seems to be the case, on the ground, perhaps, that the less of a bad thing we have, the better.

Many persons, in building wooden bridges, take no pains to get iron rods which are suitable for such work, but purchase what is easiest to be had in the market, and in many cases never find that the iron was bad until a bridge tumbles down. There are, without the slightest question, hundreds of bridges now in use in this country, which, as far as mere proportions and dimensions go, would appear to be entirely safe, but which, on account of the quality

of the iron with which they are made, are entirely unsafe; and there always will be, as long as public officials purchase iron which they know nothing about, to put into bridges. When a bridge is finished, the ordinary examinations never detect the quality of the iron; so that the wise remarks of many inspectors, or the opinions of those in charge of these structures, as to the exact condition of a bridge, are of little or no value.

We often hear iron bridges condemned, while wooden ones, so called, are supposed to be free from defects. It does not seem to occur to persons holding such ideas, that wooden bridges rely just as much upon the strength of the iron rods that tie the timbers together, as upon the timber. As a matter of fact, where one iron bridge

falls, a dozen wooden ones do the same thing. One very decided advantage which an iron bridge has over a wooden one, is that we can make sure of good iron in the beginning, and that we can also be sure that it does not decay; while, however good our timber may be in the beginning, we never can be entirely sure of its condition afterwards. There are wooden bridges now standing in this country, all the way from sixty to eighty years old, which are apparently as good as ever; while there are others, not ten years old, which are so rotten as to be unfit for use. It will not do to assume, that, because no defects are very evident in a wooden bridge, therefore it has none. When a wooden bridge, originally made of only fair material, has been in use under railroad trains for twenty-five or

thirty years, and in a position where timber would naturally decay, we are bound to suspect that bridge. To assume such a bridge to be all right until we can prove it to be all wrong, is not safe. To assume a bridge to be all wrong until we can prove it to be all right, is a safe method, though not a popular one. Any person who has had occasion to remove old wooden bridges, will recall how often they look very much worse than was anticipated.

There is one defect in railway bridges which has often led to the most fearful disasters, and which, without the slightest question, can be almost entirely, if not entirely, removed, and at a moderate cost. At least half the most disastrous failures of railroad bridges in the United States have been due to a defective system of flooring.

With a very large proportion of our bridges, the failure of a rail, the breaking of an axle, or any thing which shall throw the train from the track, is almost sure to be followed by the breaking down of the bridge. The cross-ties are in many cases very short, and the floor is proportioned for a train *on* and not *off* the rails. When an engine on such a floor leaves the track, it plunges off the ends of the cross-ties into the open space between the stringers and the chords, and generally wrecks the bridge. To prevent this, the cross-ties should be long and well supported, and placed so close that a derailed engine cannot cut through them. The track should also be provided with guard-timbers well fastened, and the width between the trusses should be so great that the wheels of a derailed train will be stopped by

the guard-rail before the side of the widest car can strike the truss.

The importance of a substantial floor system has been very fully recognized by the railroad commissioners of Massachusetts, who have recently issued a very suggestive circular, accompanied by numerous examples of track construction for railway bridges. If this circular receives proper attention, it is sure to produce good results.

Another point which has often been neglected, is making sufficient provision to resist the force of the wind. A tornado, such as is not uncommon in this country, will exert a force of 40 pounds per square foot, which upon the side of a wooden bridge, say of 200 feet span, and 25 feet high, and boarded up as many bridges are, would amount to a lateral thrust of no less

than 100 tons; and this load would be applied in the worst possible manner, i.e., in a series of shocks. There have been many cases in this country where bridges have been blown down; and a case recently occurred where an iron railroad bridge of 180 feet span, and 30 feet high, and presenting apparently almost no surface to the wind, was blown so much out of line that the track had to be shifted. The recent terrible disaster at the Frith of Tay was, no doubt, due to this cause.

At the time of the Tariffville catastrophe, it was gravely stated at the coroner's inquest, and by railroad officers who claimed to know about such things, that the disaster was caused by the tremendous weight of two locomotives which were coupled together, and it was stated that one engine would

have passed in safety; and directly afterwards the superintendent of a prominent railroad in New England issued an order forbidding two engines connected to pass over any iron bridges. It is all very well for a company to issue such an order, so far as it may give the public to understand that it is determined to use every precaution against disaster; but such an order may have the effect of creating a distrust which really ought not to exist. If a railway bridge is not entirely safe for two engines, it is certainly entirely unsafe for one engine and the train following; the only saving in weight by taking off one engine being the difference between the weight of that engine and the weight of the cars that would occupy the same room. For example, a bridge of 200 feet span will weigh 1,500

pounds per lineal foot. An engine and its tender will weigh 60 tons in a length of 50 feet, and a loaded freight-train may easily weigh $\frac{2}{3}$ of a ton per lineal foot. The total weight of the span, with two engines, and the rest of the bridge covered with loaded freight-cars, would thus be 320 tons. If we take off one engine, and fill its place with cars, we take off 60 tons, and put in its place 33 tons; i.e., we remove 27 tons, or just about $\frac{1}{12}$ of the working-load. Taking off a large part of the working-load, however, is taking off a very small part of the breaking-load; with a factor of safety of six, for example, taking off $\frac{1}{12}$ of the working-load is taking off less than $\frac{1}{70}$ of the breaking-load. An order, therefore, like that above, can only be of use when the working-load and the breaking-load are so nearly alike that the

actual load is a dangerous one: that is when the bridge is unfit for any traffic whatever; so that, if such an order was really needed, it would, in itself, be, in the eyes of an engineer, a condemnation of the bridge.

Having seen something of the structures which require inspecting, let us now see what kind of inspection we have in this country, and the result of it; and let us also see the inspection which we might have, and the results that might be produced. Looking first at railroad bridges, it might be supposed that no one could be so much interested in keeping such structures in good order as the companies which own those bridges, and which have the bills to pay in case of disaster. This is, of course, so; but, in spite of the fact, the Ashtabula bridge broke down, on one of the best managed lines in the country,

and cost the company over half a million dollars in damages. No railroad bridge ever broke down, which the owners were not interested in keeping safe; but there is always a desire to put off incurring large expenses until the last moment, and thus weak bridges are very often let go too long. A short time since, the superintendent of a large railroad stated plainly before a legislative committee, that many of the smaller roads were not safe to run over, but that such roads were having a hard time, and could not afford to keep their track and bridges in a safe condition. During the past ten years over two hundred railroad bridges in the United States have broken down. These bridges were all kept under such inspection as the railroad companies owning them considered sufficient, or such as they could afford; but either the

supervision was defective, or the companies knowingly continued the use of unsafe bridges, and this fault has by no means been confined to the smaller and poorer roads. It would seem, therefore, that inspection by the companies themselves has not been sufficient. It certainly has not been enough to prevent two hundred disasters in ten years. It is the custom in several of the United States to maintain what is termed a railroad commission. The original intention seems to have been for these commissions to keep the railroads under some kind of inspection, and in some way to assist in settling any questions that might arise between different companies, and between railroad companies and the public. As far as we can judge by the results produced, in the States where these commissions have been established, we can

hardly pronounce them of any very great importance. In many States, it is very certain, that, in regard to matters of inspection, the work of these boards has been simply a farce; and it could hardly be otherwise in a State which pays its commissioners only $1,000 salary, or, worse yet, as in some cases, only $500. Add to this, that in many cases the appointments have been purely political ones, and we can see the absurdity of expecting any results of value. We should hardly suppose that three men, in many cases entirely unacquainted with mechanical matters, could by riding over a railroad once or twice a year, occasionally getting out to examine the paint on the outside of the boards, which conceal a truss from view, judge very correctly of the elastic limit of the iron rods which they have never seen,

and of which they do not even know the existence.

For ample proof of the utter inefficiency of the present system, we have only to compare the reports of the railroad commissioners in almost any State, with the actual condition of the structures described. In one State a late annual report covers a whole railroad with the remark, "All of the bridges on this line are in excellent order;" and yet there were at that very time, and are now, on that road, several large wooden bridges with a factor of safety referred to the breaking-weight of not over *two* under a fair load, assuming the iron rods to be of the very best material,—a point upon which there is no evidence whatever.

There is, in fact, no difference which

any ordinary inspection would detect between these bridges as they stand to-day, and the Tariffville bridge as it stood the day before it fell. In another State, an iron bridge is in use under heavy trains, which has a factor of only 2½ instead of 6, and yet the State report pronounces it an excellent structure and a credit to the railroad company, which recklessly allows its trains to pass over it. In yet another State, the commissioners in 1874 reported that a certain bridge should be removed; and this was quite correct, as it was an eminently unsafe bridge. In 1875 they suggested the same thing again. In 1876 they say, "This bridge must be rebuilt the coming spring." In 1877 they again reported, "This bridge must be rebuilt before the spring opens. It is old, and will not

be safe for the passage of trains over it, if the ice or freshet should take away the temporary trestles, which now in a great measure support the truss."

A year later than that, in 1878, a public protest was made against the further use of that bridge, as the lower chords were rotten, broken, pulled apart, and the only thing that held it up was a trestle, liable at any time to be knocked out by the ice; and yet, after all this, in reply to the protest, the commissioners replied that they had just "tested" the bridge by running an engine over it, and pronounced it "safe for the present," whatever that may mean. Now, just how it was that this bridge, which was old, rotten, and worn out, which the commissioners themselves had condemned for four successive years,

which they had said two years before must be rebuilt the coming spring, and which relied entirely upon a trestle liable at any time to be carried away, had suddenly become "safe for the present," is not plain to see.

Evidently such inspection as this is of no value. It is exactly this utterly incompetent and dishonest inspection, this guessing that a bridge will stand until it falls, that lies at the bottom of half the disasters in the country. It is under exactly such inspection that those wretched traps, the Ashtabula and Tariffville bridges, fell, and killed over one hundred people. No wonder that railroad officials have an undisguised contempt for State inspection. While in a few States the inspection is not quite so bad as that referred to, as a general thing it is no better; and we have no right to expect any thing better

under the present system. The State inspection which we have had throughout this country has not prevented the breaking down of one hundred bridges in the past ten years. Twenty-five States have railroad commissions; but in nine of them the commission consists of only a single man, who, in some cases, is paid only $500 a year. A State can pay $500 a year for having its bridges inspected, and it will get such service as never did and never will prevent a disaster; or it can pay a good price for competent inspection, which will be worth ten times the money to the State. The money which the Lake Shore Railroad paid in damages for the Ashtabula disaster alone, would have employed permanently six men at $5,000 a year each, and a hundred lives would have been saved besides.

With regard to highway bridges, we are, if possible, even worse off than in regard to railway bridges; for in the case of such structures, neither the owners nor the State make any pretence at inspection. It is impossible to say how many highway bridges have broken down during the past ten years, but it is estimated by bridge-builders that the number cannot be less than two hundred. This is, no doubt, far within the truth; and by far the larger part of these structures are not old wooden bridges, but are new bridges of iron.

If we knew positively that in just six months a terrible disaster would occur under the present system of bridge inspection, and knew also, that, by a better system, such disaster would certainly be prevented, it is possible that a change might be made.

We know that a proper method of building and inspecting bridges would certainly have prevented the disasters at Ashtabula, Tariffville, and Dixon. We know that the inspection which those bridges received, did not prevent three of the most fearful disasters the country has ever seen. Admitting, now, that structures so important to the public safety as bridges, both upon roads and railroads, ought to be kept under rigid inspection and control, and that no system at present existing has been able to prevent the most fearful catastrophes, what shall we do? Directly after the Ashtabula disaster, the Ohio legislative committee, appointed to investigate that affair, presented to the Legislature a bill, "To secure greater safety for public travel over bridges," in which was plainly specified the loads for which all

bridges should be proportioned, the maximum strains to which the iron should be subjected, and a method for inspecting the plans of all bridges before building, and the bridges themselves during and after construction. The governor, with the consent of the Senate, was to appoint the inspector for a term of five years at a salary not exceeding $3,000 a year, such inspector to pass a satisfactory examination before a committee of the American Society of Civil Engineers, themselves practical experts in bridge construction, and he was also to take a suitable oath for the faithful performance of his duty. This bill never became a law. An appropriation was made for a short time to pay for certain examinations, and there the matter stopped.

The committee of the American Society

of Engineers were not agreed upon this matter. Messrs. James B. Eads and Charles Shaler Smith suggested the appointment in each State of an expert, to whom all plans should be submitted, and by whom all work should be inspected, — such expert to have been examined and approved by the American Society of Civil Engineers. The inspector was also to visit the scene of every accident, so called, and to ascertain, as far as possible, the cause. Messrs. T. C. Clarke and Julius W. Adams believed, that, in the present state of public opinion, the above method would be impracticable, and feared, that, if inspectors were appointed, it would be by political influence, and that the result would be worse than at present, as the inspectors would be inefficient, and yet, to a great

extent, would relieve the owners of bad bridges from legal responsibility. They held that the best that could be done would be to provide means, in case of disaster, to fix plainly the responsibility, and recommended, First, that the standard for strength fixed by the Society should be the legal standard; and, in case it should be found that any bridge was of less strength than this, it should be taken as *prima facie* evidence of neglect on the part of the owners. Second, that no bridge should be opened to the public until a plan giving all dimensions, strains, and loads, sworn to by the designers and makers, and attested by the corporation having control of it, had been deposited with the American Society; and further, that the principal pieces of iron in the bridge should

be stamped with the name of the maker, place of manufacture, and date. Messrs. A. P. Boller and Charles Macdonald looked rather toward effecting the desired result by so directing public sentiment by keeping the correct standard for bridges before it, that it would eventually compel the passage of the necessary laws.

Whether it is possible, in this country, to make an appointment dependent purely upon honesty and capacity, and free from political influence, may well be doubted. No competent engineer would be willing to accept a position which would place upon him so great a responsibility, except under a very carefully devised plan. A very considerable force of inspectors would be required to carry out a system which should produce the desired result. The amount of

work to be done at the commencement would be very great, as no proper inspection has ever been made of the greater part of the bridges in the country, of which the number is very large. If any such plan as above suggested should be found feasible, the inspectors should have in their possession a complete set of plans of every bridge of importance in the State, with all the computations of its strength, and as complete a history of each structure from its commencement as can be made up, all this to be supplemented by periodic examinations. If, from such records, we find that a bridge was made of ordinary green timber twenty-five years ago, and that it has been getting rotten ever since; that it has rods of common merchant iron that were bought by some person, not specially acquainted with

the business, from an unknown firm, — we had better pull it down before it falls. If, from such records, we find an iron bridge built twenty-five years ago by an unknown company, with iron, at best, of a doubtful quality, and having a factor of three or four for the rolling-stock and speeds of twenty years ago, instead of a factor of six for the rolling-stock and speeds of to-day, we had better remove that bridge before it removes itself.

Such a record would be the property of the State, always accessible to any one, and would be handed down, so that the knowledge of one person would not expire with his term of office. No bridge should be erected in any State without first submitting the plans to the inspector, and receiving his approval, and depositing with him a com-

plete set of the plans and computations for the work. By this approval is not meant that the inspector is merely to give a favorable opinion as to the plan, but that he is to find, as a matter of fact, whether the proposed dimensions and proportions are such as will make a safe bridge — and just what a safe bridge is, can be plainly defined by law, as it is in Europe, and as it has been proposed by the American Society of Civil Engineers. For example, if the law says that an iron railway bridge of 100 feet span shall be proportioned to carry a load of 3,000 pounds per lineal foot besides its own weight, and that, with such a load, no part shall be strained by more than 10,000 pounds per inch, all the inspector has to do is to go over the figures, and see that the dimensions given on the plan are such as

will enable the bridge to carry the load without exceeding the specified strains. When the work is erected, the inspection must show that the plan has been exactly carried out, that the details are good, and proper evidence of the quality of the material used should also be given. Such inspection as this would at once prevent the erection of bridges like those at Ashtabula and Tariffville, and would save the public from such traps as those that fell at Dixon and at Groveland. Perhaps the most difficult thing to do will be to get satisfactory evidence in regard to the bridges that have been for a considerable time in use, and of which we do not know the history. This will be especially true in regard to the wooden bridges, of which there are so many about the country. Not only is it very difficult to be sure

of the exact condition of the timber, but it is equally hard to tell any thing about the iron. The Tariffville bridge fell on account of defective iron, and the defect was of such a nature as to defy any ordinary inspection. What do we know to-day of the quality of the iron rods in any wooden bridge in Massachusetts? It is very doubtful if the best inspection we have in the United States at the present time would have found any defect so evident in the Tariffville bridge as to condemn it as unfit for the passage of trains. There are hundreds of exactly such bridges all over New England, as far as we can tell by the best inspection we now have, made on the same plan, with no more material, and of which we know just as little of the quality of the iron as we did in the Tariffville bridge.

Of course we cannot expect to get a perfect system all at once. Any plan which might be proposed would, no doubt, be found more or less defective at first. We can hardly get a system worse than the one we now have, which allows forty bridges to break down every year. We may get a better one. To make the public see the need of such a system is the first step to be taken.

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